Salmonella epidemiology and control in pork: questions addressed and questions remaining.

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Abstract: To assess trends in *Salmonella* research in pork production, the listings in a scientific database (CAB, International) were screened for the period 1990-2000. Reported publications increased approximately three fold, from 16 in 1990 to approximately 50 per year from 1997 through 2000. The breakdown of reported research by area of focus was summarized for the period 1995 through 2001 by screening citations reported by three abstracting services (AGRICOLA, CAB International, and MEDLINE). Many important questions remain for further investigation in each area. Judged on numbers of publications, relative strengths were identified in current scientific literature for pre-harvest epidemiology and *Salmonella* detection, and relative weaknesses were identified in economics and public policy related to control of *Salmonella* in pork.

Keywords: *Salmonella* and Pork, *Salmonella* Research, *Salmonella* in Swine Production, Zoonoses

Introduction: Research on *Salmonella* in pig production and the pork food production chain, including pig rearing, slaughter-processing, and further steps in the food chain, has accelerated over the past 10 years. Increased awareness and public concern over food safety generally, and bacterial food safety specifically, is often cited as the driving force that has lead researchers and funding bodies to prioritize *Salmonell*a. While the amount of research completed is substantial, important questions remain. The goal of this paper is to provide readers a synopsis of the trends in scientific research since the 3 rd International Symposium on the Epidemiology and Control of *Salmonella* (Washington, D.C., Aug. 5-7, 1999), to identify areas of relative weakness in the knowledge base, and to frame some of the new areas for investigation that are opening.

Materials and Methods: To assess trends in research on *Salmonella* in the pork chain, the scientific literature since 1995 was surveyed by searching three major international abstracting databases: CABI, AGRICOLA, and Medline. The search was conducted in three phases. First, the initial searches included articles containing the text strings "*Salmonell*a," and one of "pigs" and variants of "pork."

Second, the search was restricted to require at least one of the following terms: treatment, prevention, detection, economics, control, management, regulation, surveillance or monitor. The titles of the first more inclusive search were compared with those in the more restrictive search, and any relevant articles identified only in the more comprehensive search were included. Duplicate titles were removed. Proceedings papers were removed, since they are inconsistently catalogued. Finally, the abstract of each article was read for relevance, and each article was classified into one or more areas reflecting the major topic(s) of the paper. Area categories were a modification of areas used in the 3 rd symposium, including the following categories: Epidemiology and intervention at both production (pre-harvest) and post-harvest levels, detection, microbiology, pathogenesis, control programs (regional or national), antimicrobial resistance, economics and human health implications.

To assess the trends in number of publications over the past 10 years, the same methodology described above was applied to the CABI abstract database, except that articles were not categorized by area of focus. In addition, since the purpose of this summary was to emphasize numeric trends and not absolute numbers of publications, titles but not abstracts of the resulting papers were screened for relevance. Consequently, the estimate of total numbers of papers may be under or over-estimated.

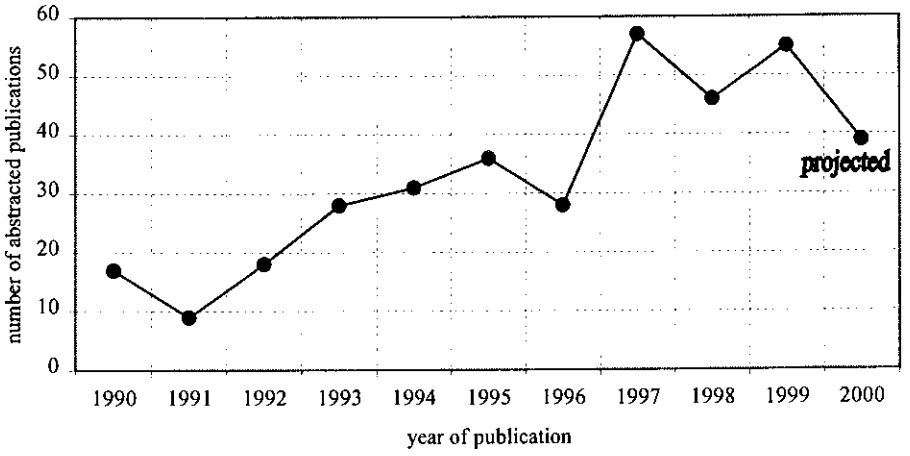

Figure 1. Growth in the number of *Salmonella* articles directly related to pork as listed by an international agricultural abstracting service (CABI).

For year 2000 the number of publications was adjusted upwards by dividing the observed number by 0.8, to reflect the expected 80% completion of abstracts as of June 30, 2001 (Taylor).

Highlights of specific topics published since January 1, 1999, are briefly discussed to provide a sense of the issues addressed. This dates chosen since this approximates the closing date for preabstraction submissions to the 3 rd symposium. Symposia proceedings were not included in these highlights, and individual citations of work are not listed due to limitations of space (seen note in reference section).

Results: Viewed over the past decade, the number of scientific papers on *Salmonella* in pork has grown dramatically. The number of abstracted articles found in CAB abstracts has grown from 16 in 1990, to approximately 50 per year since 1997, for a total of 351 abstracted publications. This upsurge in research activity has paralleled the changes in regulation, with regulations in both the United States and the European Union coming into effect during the period.

Table 1. The number of *Salmonella* and pork scientific papers reported by areas of focus, found in three major scientific abstracting services: CABI, AGRICOLA, and Medline.

Area	1995	1996	1997	1998	1999	2000[1]	2001[2]	totals
Production epidemiology	7	15	20	10	20	10	2	84
Production intervention	10	4	15	9	19	14	3	74
Detection	10	7	11	12	12	13	2	67
Pathogenesis and microbiology	12	12	10	10	18	18	1	81
Antimicrobial resistance	2	2	9	17	14	8		52
Human health	4	7	10	9	8	11	2	51
Post-harvest intervention	9	9	12	6	8	5	1	50
Post-harvest epidemiology	3	4	9	4	9	4	1	34
Control programs	4	4	4	3	3	1	19	
Review articles	1		1	1	4	1		8
News and commentary	1	1	4	1	1			9
Economics					1		1	2
Public policy				1		1		2
Tally by year[3]	63	61	105	84	117	88	15	533

1 Estimated to be 80% complete at the time of writing. (Roberts, R.)
2 Partial, based on citations entered as of June 1, 2001.
3 Tallies exceed the number of publications per year, since each publication may be classified into more than one area of focus.

A broader search of papers published over the past five years identified 430 papers on *Salmonella* and pork abstracted in the CABI, Medline and AGRICOLA databases (Table 1). Since approximately 20% of papers covered more than one area, the sum of all citations was 530. Production food safety, including both epidemiology and intervention, account for 158 of 430 papers, or 37% of citations. Antimicrobial resistance, while included as a topic in 12% of citations, is becoming relatively and absolutely more common. During the period 1995-1997, 13 papers

(10%) covered resistance to antimicrobials, while in the period 1998-2001, 39 papers (16%) dealt with the topic. In contrast, post-harvest interventions and epidemiology have been relatively stable in absolute numbers, and actually declined as a proportion of citations overall during the period. During the period January 1, 1999 through June 30, 2001, 169 articles were published and included in the three databases summarized (Table 1). When summarized into the three categories of production food safety, post-harvest food safety, and other, the numbers of publications in each category were 56, 25 and 92, respectively.

Discussion/Conclusions: The number of abstracted publications grew steadily from 1990 to 1995, then appears to have reached a plateau. The increase in publications parallels changes in regulation in several countries, and an increase in available support for research. However, the plateau since 1995 may suggest that existing funding sources or existing research personnel / infrastructure have been saturated. Simply counting titles, as was done here, may not accurately reflect the amount of substantial knowledge generated. The complexity and scope of research papers has continued to increase in recent years, especially as new knowledge is built upon already published literature. In this way, a stagnant number of titles may still reflect an increasing rate of knowledge accumulation.

Although the abstracting services chosen and the method of searching should have returned a broad assessment of *Salmonella* research associated with pork, it will be incomplete. The abstracting services are selective in their inclusion of papers, introducing an uncontrolled bias to these summaries. In addition, there are many papers on these topics that have relevance to pork, but without phrases related to pigs or pork in the title or abstract. For example, many important lessons can be drawn from *Salmonella* research in other food producing animal species, and much of the relevant work on testing, pathogenesis and microbiology is reported without reference to a host species.

Judging by numbers of publications, the largest share of publications have been and continue to be focused on pre-harvest epidemiology and interventions. The total number of publications since 1999 suggests a strong commitment of researchers and funding bodies to address on-farm issues.

The distribution and occurrence of *Salmonella,* either within herds or among groupings of herds, continues to be a major theme of epidemiologic investigations with 12 publications. Outbreaks have also been investigated in three publications.

Assessment of risk factors have been reported for both microbiological and serological *Salmonella* positive status. Several additional risk factor assessments have been reported in proceedings of symposia since 1999, and we can expect to see additional final reports on risk factor studies in the near future. Risk factors, as reported in observational epidemiological studies, can provide useful data for prioritising efforts in the development of intervention strategies and to provide guidance for future investigative work.

Investigation of individual interventions have been reported by at least 16 publications during the period. Factors assessed included vaccination, competitive exclusion, prebiotics, antimicrobials, passive antibodies, lymphokines, feed withdrawal and transportation. The control of *Salmonella* in manure and waste treatment byproducts have also been reported by three publications.

The reported human health implications of pork related *Salmonella* included outbreak investigations, an attempt to correlate serotypes between food animal and human isolations, an investigation into a commercial kitchen, and an analysis of the proportion of human cases of *Salmonella* associated with pork consumption. The quantitative assessment of risk due to pork remains an area with relatively sparse data, in spite of the fact that this assessment is critical to rational development of public health policy. Of particular note is the publication of an outbreak of a multi-drug resistant strain of *Salmonell*a. This study made a case for the linkage of resistant strains on farms and the outbreak of infection among humans.

Among 16 titles identified since 1999 covering post-harvest epidemiology, topics have included descriptive studies of the occurrence of *Salmonella* in carcasses, meat and facilities, traceback of *Salmonella* contaminated meat products, and characterization of serotypes identified at slaughter. Reports on post harvest interventions have included effects of food additives, storage temperatures and times, and the effect of practices in the slaughter process on *Salmonella* contamination.

Antimicrobial resistance was a major focus of 23 titles during the period. The description of the prevalence of resistance to multiple antimicrobials was the most common topic, including a special focus on resistance to quinolone antibiotics. Other topics included investigations of potential linkages between resistance in pig and pork isolates and human isolates, and development of systems to monitor changes in resistance patterns in porcine isolates. Many epidemiologic topics remain for further investigation, including additional information on the potential transfer of resistance from pigs / pork to humans and the transfer from humans to pigs and pork, and the spread of resistance genes and resistant organisms among pigs.

Enzyme linked immunosorbant assays (ELISA) detecting *Salmonella* antibodies were the subject of eight titles, including the application or modification of published methods in new settings, and the development of new techniques. No reports were identified describing the kinetics of antibody response to *Salmonella* spp. in experimental or natural / commercial pig production settings. Refinements in culture methods to detect *Salmonella* and comparisons of detection methods were reported, as were development of PCR techniques and other genetic detection methods. Opportunities still remain to develop or refine techniques to rapidly identify *Salmonella* contaminated pigs or pork, and to accurately type or categorize isolates by serotype, genetics or other markers. Further description of the performance of existing tests in population settings is also needed.

Relatively few titles were identified in the area of economics and public policy issues. Development of methods to control *Salmonella* in a way that is economically feasible is essential, yet relatively little has been reported during the period. Further, much of *Salmonella* control includes an element of public policy. The integration of biological science and economics, and public policy related to *Salmonella* control are areas that should be explored more fully.
No titles were identified that focus on the educational needs of farmers, processors, or other participants in the pork chain. A clear assessment of these needs would aid in the development of control and outreach programs.

Conclusions: Research on salmonella and pork has accelerated over the past 10 years[1], but judged by the number of abstracted titles, research output appears to have reached a plateau since 1997. Relative strengths in published literature are primarily in the areas of production food safety, with secondary focus on post-harvest and *Salmonella* detection issues. Research on antimicrobial resistance is becoming increasingly common. Opportunities for research progress remain in all areas, but especially needed is research on the interaction of the biology of *Salmonella* control and economics, public policy issues, and the assessment of education and outreach needs.

References:4

AGRICOLA, Beltsville: National Agricultural Library (Producer)
CAB Abstracts, Wallingford, U.K.: CAB International (Producer)
MEDLINE, Bethesda, MD: National Library of Medicine (Producer).
Taylor R. 2001. Content Manager, Animal Sciences, CABI, personal communication.

[1] the full reference list is available at the web site http://www.cvm.uiuc.edu/safepork